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AMOLED : An Emerging Trends in LED

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Abstract—**This paper presents the concept of Active Matrix Organic Light Emitting Diodes as a modern trend in Light Emitting Devices. This paper introduces AMOLED device structure and operation, AMOLED materials, Evolution of AMOLED. AMOLED are used in television screens, computer monitors, small, portable system screens such as mobile phones and PDA, watches, advertising, information, and indication. AMOLED are also used in light sources for space illumination and in large-area light-emitting elements. Due to their early stage of development, they typically emit less light per unit area than inorganic solid-state based LED point-light sources. Different fabrication processes and technologies are covered. Also Passive-Matrix OLED driving schemes are outlined. This paper also describes the market potential of AMOLED by taking modern trends in technology into account.**

Index Terms—**AMOLED, Luminescence, Light Emission, OLED, Energy Efficiency.**

I. Introduction

ACTIVE Matrix Light Emitting diode is a display technology for use in mobile devices and televisions. OLED describes a specific type of thin-film display technology in which organic compounds form the electroluminescent material, and active matrix refers to the technology behind the addressing of pixels. Since it is an advancement of OLED technology, AMOLED features a great deal of the same characteristics as its predecessor. In fact, the similarities far outnumber the differences. OLED, at its core, is a simple light-emitting diode whose luminescence is provided by a film made of organic components, as opposed to traditional inorganic materials. By running an electric current through the electrodes in an OLED, it can emit light usable in a variety of devices, from flashlights to computers.

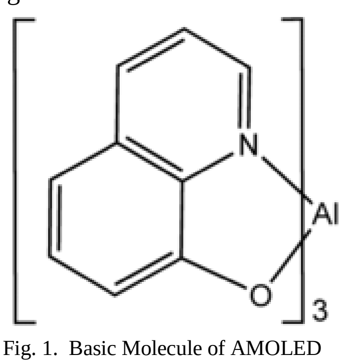

Fig. 1. Basic Molecule of AMOLED

The basic principle behind the working of AMOLED is Electroluminescence. Electroluminescence (EL) is an optical phenomenon and electrical phenomenon in which a material emits light in response to the passage of an electric current or to a strong electric field. This is distinct from black body light emission resulting from heat, from a chemical reaction, sound, or other mechanical action.

Electroluminescence is the result of excitation of electrons which releases their energy as photons - light. Prior to recombination, electrons and holes may be separated either by doping the material to form a p-n junction (in semiconductor electroluminescent devices such as light-emitting diodes) or through excitation by impact of high-energy electrons accelerated by a strong electric field (as with the phosphors in electroluminescent displays). Regarding creation of color AMOLED has more control over colour expression because it only expresses pure colours when electric current stimulates the relevant pixels. The primary colour matrix is arranged in red, green and blue pixels which are mounted directly to a printed circuited board. Each individual AMOLED element is housed in a special micro cavity structure designed to greatly reduce ambient light interference that also improves overall colour contrast. The thickness of the organic layer is adjusted to produce the strongest light to give a colour picture. Further, the colours are refined with a filter and purified without using a polarizer to give outstanding colour purity.

II. History

The first observations of electroluminescence in organic materials were in the early 1950s by A. Bernanose and co-workers at the Nancy-University, France. They applied high-voltage alternating current (AC) fields in air to materials such as acridine orange, either deposited on or dissolved in cellulose or cellophane thin films. The proposed mechanism was either direct excitation of the dye molecules or excitation of electrons.

In 1960, Martin Pope and co-workers at New York University developed ohmic dark-injecting electrode contacts to organic crystals. They further described the necessary energetic requirements (work functions) for hole and electron injecting electrode contacts. These contacts are the basis of charge injection in all modern AMOLED devices. Pope's group also first observed direct current (DC) electroluminescence under vacuum on a pure single crystal of anthracene and on anthracene crystals doped with tetracene in 1963 using a small area silver electrode at 400 V. The proposed mechanism was field-accelerated electron excitation of molecular fluorescence.

Pope's group reported in 1965 that in the absence of an external electric field, the electroluminescence in anthracene crystals is caused by the recombination of a thermalized electron and hole, and that the conducting level of anthracene is higher in energy than the excited energy level. Also in 1965, W. Helfrich and W. G. Schneider of the National Research Council in Canada produced double injection recombination electroluminescence for the first time in an anthracene single crystal using hole and electron injecting electrodes, the forerunner of modern double injection devices. In the same year, Dow Chemical researchers patented a method of preparing electroluminescent cells using high voltage (500–1500 V) AC-driven (100–3000 Hz) electrically insulated one millimetre thin layers of a melted phosphor consisting of ground anthracene powder, tetracene, and graphite powder. Their proposed mechanism involved electronic excitation at the contacts between the graphite particles and the anthracene molecules.

Device performance was limited by the poor electrical conductivity of contemporary organic materials. This was overcome by the discovery and development of highly conductive polymers.

Electroluminescence from polymer films was first observed by Roger Partridge at the National Physical Laboratory in the United Kingdom. The device consisted of a film of poly (n-vinyl carbazole) up to 2.2 micro metres thick located between two charge injecting electrodes. The results of the project were patented in 1975 and published in 1983.

The first diode device was reported at Eastman Kodak by Ching W. Tang and Steven Van Slyke in 1987. This device used a novel two-layer structure with separate hole transporting and electron transporting layers such that recombination and light emission occurred in the middle of the organic layer.

This resulted in a reduction in operating voltage and improvements in efficiency and led to the current era of AMOLED research and device production.

Research into polymer electroluminescence culminated in 1990 with J. H. Burroughes at the Cavendish Laboratory in Cambridge reporting a high efficiency green light-emitting polymer based device using 100 nm thick films of poly (p-phenylene vinylene).

III. CONSTRUCTION

It consists of an emissive layer, a conductive layer, a substrate, and both anode and cathode terminals. The emissive layer, where light is made by the emission of radiation whose frequency is in the visible region is made up of organic plastic molecules that transport electrons from the cathode and the polymer used is polyfluorene. The conductive layer is made up of organic plastic molecules that transport holes from the anode and the conducting polymer used is polyaniline. The substrate that supports AMOLED is made up of flexible plastic, inexpensive glass or metal foil. Anode, that removes electrons when a current flows through the device, is generally made up of Indium tin oxide and it is transparent and cathode that injects electrons when a current flows through the device is made up of metals like aluminium and calcium, which may or may not be transparent depending on the type of AMOLED.

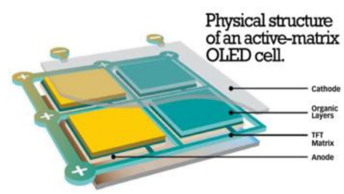

Fig. 2. Physical Structure of an active-matrix OLED cell

IV. WORKING

A typical AMOLED is composed of a layer of organic materials situated between two electrodes, the anode and cathode, all deposited on a substrate. The organic molecules are electrically conductive as a result of delocalization of pi electrons caused by conjugation over all or part of the molecule. These materials have conductivity levels ranging from insulators to conductors, and therefore are considered organic semiconductors. The highest occupied and lowest unoccupied molecular orbitals (HOMO and LUMO) of organic semiconductors are analogous to the valence and conduction bands of inorganic semiconductors.

Originally, the most basic AMOLEDs consisted of a single organic layer. One example was the first light-emitting device synthesised by J. H. Burroughes et al., which involved a single layer of poly (p-phenylene vinylene). However multilayer AMOLEDs can be fabricated with two or more layers in order to improve device efficiency. As well as conductive properties, different materials may be chosen to aid charge injection at electrodes by providing a more gradual electronic profile, or block a charge from reaching the opposite electrode and being wasted. Many modern AMOLEDs incorporate a simple bilayer structure, consisting of a conductive layer and an emissive layer. More recent developments in OLED architecture improves quantum efficiency (up to 19%) by using a graded heterojunction. In the graded heterojunction architecture, the composition of hole and electron-transport materials varies continuously within the emissive layer with a dopant emitter. The graded heterojunction architecture combines the benefits of both conventional architectures by improving charge injection while simultaneously balancing charge transport within the emissive region.

During operation, a voltage is applied across the AMOLED such that the anode is positive with respect to the cathode. A current of electrons flows through the device from cathode to anode, as electrons are injected into the LUMO of the organic layer at the cathode and withdrawn from the HOMO at the anode. This latter process may also be described as the injection of electron holes into the HOMO. Electrostatic forces bring the electrons and the holes towards each other and they recombine forming an exciton, a bound state of the electron and hole. This happens closer to the emissive layer, because in organic semiconductors holes are generally more mobile than electrons. The decay of this excited state results in a relaxation of the energy levels of the electron, accompanied by emission of radiation whose frequency is in the visible region. The frequency of this radiation depends on the band gap of the material, in this case the difference in energy between the HOMO and LUMO.

As electrons and holes are fermions with half integer spin, an exciton may either be in a singlet state or a triplet state depending on how the spins of the electron and hole have been combined. Statistically three triplet excitons will be formed for each singlet exciton. Decay from triplet states (phosphorescence) is spin forbidden, increasing the timescale of the transition and limiting the internal efficiency of fluorescent devices. Phosphorescent organic light-emitting diodes make use of spin–orbit interactions to facilitate intersystem crossing between singlet and triplet states, thus obtaining emission from both singlet and triplet states and improving the internal efficiency.

Indium tin oxide (ITO) is commonly used as the anode material. It is transparent to visible light and has a high work function which promotes injection of holes into the HOMO level of the organic layer. A typical conductive layer may consist of PEDOT:PSS as the HOMO level of this material generally lies between the work function of ITO and the HOMO of other commonly used polymers, reducing the energy barriers for hole injection. Metals such as barium and calcium are often used for the cathode as they have low work functions which promote injection of electrons into the LUMO of the organic layer. Such metals are reactive, so require a capping layer of aluminium to avoid degradation.

Single carrier devices are typically used to study the kinetics and charge transport mechanisms of an organic material and can be useful when trying to study energy transfer processes. As current through the device is composed of only one type of charge carrier, either electrons or holes, recombination does not occur and no light is emitted. For example, electron only devices can be obtained by replacing ITO with a lower work function metal which increases the energy barrier of hole injection. Similarly, hole only devices can be made by using a cathode comprised solely of aluminium, resulting in an energy barrier too large for efficient electron injection.

V. ADVANTAGES

1) AMOLED are thinner, lighter and more flexible than the crystalline layers in an LED or LCD. The plastic, organic layers of an OLED are 100 to 500 nanometres thick or about 200 times smaller than a human hair.
2)They are brighter than LEDs because the organic layers of an AMOLED are much thinner than the corresponding inorganic crystal layers of an LED. Also they do not require glass for support which absorbs some light.
3)It has ability to emit light from a surface, low heat generation, and environmentally sound compared to fluorescent lamps.
4)They do not require backlighting like LCDs as they generate light themselves, so they consume much less power than LCDs.
5)They are easier to produce and can be made to large sizes because they are essentially plastics, which can be made into large, thin sheets.
6)They can enable a greater artificial contrast ratio that is measured in purely dark conditions and have better viewing angle compared to LCDs because AMOLED pixels directly emit light.
7)They have a faster time response than standard LCD screens.
8)AMOLED is the most eco-friendly display structure requiring a low amount of energy consumption that only a specific spot in need of the light flow represents the image.
9)AMOLEDs can also have a faster response time than standard LCD screens. Whereas LCD displays are capable of between 2 and 16 ms response time offering a refresh rate of 60 to 480 Hz, an AMOLED can theoretically have less than 0.01 ms response time, enabling up to 100,000 Hz refresh rate.
10)The efficiency of AMOLED is 20cd/A to 40cd/A with a lifetime of 50,000 hours and power consumption is 62W

VI. DISADVANTAGES

1)Limited lifetime of the organic materials. While red and green OLED films have longer lifetimes, blue organics currently have much shorter lifetimes. However, the lifespan of AMOLED displays can be increased by improving light outcoupling.
2)The intrusion of water into displays can damage the organic materials and limit the longevity of more flexible displays. Therefore, improved sealing processes are important for

practical manufacturing.

3)The fabrication of the substrate is complex and expensive process in the production of TFT LCD, so flexible substrates such as roll-up displays and displays embedded in fabrics or clothing can be used.

4) It can be easily damaged by water.

5)AMOLED have much more expensive manufacturing process.

VII. APPLICATIONS

1)The AMOLED are basically used in the touch screens of mobile phones, at the same time it is also used in computers, netbooks, tablet pc.

2)AMOLED displays are used in a growing numbers of applications supporting dismounted soldiers and commanders in situational awareness, thermal imaging, simulation and training. This technology is being integrated in more military systems and on the long run is expected to replace most small form-factor LCD displays. Among the applications where AMOLED technology is already maturing are near-eye displays of “virtual images” When projected on a head mounted, helmet mounted or visor (see-through) display, such image appears like an image in a movie theater or on a computer monitor, but is created using magnifying optics from a very small display near to the eye. Such an image displayed with very high resolution, can appear solid and real, or made see-through depending on the type optics used.

VIII. FUTURE ASPECTS

Combining a transparent AMOLED display panel with a Solar Panel at the back. As we know, these transparent AMOLED panels are made out of all transparent materials, so they transmit high amounts of light through them. A high efficiency(40% or more) Solar panel placed at the back can help increase the battery life of Smartphones, so they charge fast(because of smaller battery), but last long(due to charge from Solar panel). Some calibration might be needed to acheive color accuracy like that of normal AMOLED display.

This type of setting will in no away affect the aesthetics of the device as it's completely placed inside the device. The cost of very high efficiency solar panels may be very high too, but it should be very less for sizes as small as smartphone display.

IX. CONCLUSION

Active matrix Organic light emitting diodes promise to make electronic viewing more convenient and ubiquitous as they are more energy efficient. OLED is so revolutionary that in the field of illumination it is being hailed as “the first discovery since Edison”. Today, OLED technology is widely seen as a next generation component for flat panel displays and is expected to become a key technology in the development of flexible displays view the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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